2010 STUDENT UAS COMPETITION
Journal Paper
Élise Team – University of Sherbrooke

Presented by :
Maxime Boileau
Louis Corriveau
Mathieu Gaumond
Dominic Lallier Daniels
Patrick Lepage
Patrice Lépine
Michaël Lévesque Leduc

http://pages.usherbrooke.ca/elise/
projet.elise@listes.usherbrooke.ca

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1 Introduction

The Élise Project came to life as a final design project within the University of Sherbrooke's mechanical engineering undergraduate program. A team of 10 students worked for two years to design and manufacture a working unmanned aerial drone. The team aimed to develop a viable solution regarding the high costs related to aerial surveillance means utilized in current search and rescue operations. Use of standard manned aircraft and helicopters for such missions means high operation cost, the need for complex infrastructures and often putting the crew's lives at risk.

Thus, the Élise team proposes as an alternative an aerial reconnaissance drone capable of vertical take-off and landing while retaining long range flight capabilities, making it easier to use in search and rescue operations where optimal take-off conditions aren't always readily available. Also, the vehicle being unmanned, it poses no risk to the pilot and offers a low cost solution to standard means of aerial surveillance. The proposed solution also requires minimal infrastructure as it is deployable by a two-man team and requires minimal tooling for assembly or disassembly.

The Élise project has already participated in some other events, including a victory at the UVS Canada UAV competition in May of 2009 as well as a victory in the 2010 Quebec Engineering Competition, where the team was awarded a special mention for technical excellence, which allowed to team to move on to the Canadian Engineering competition where the team finished in 4th place overall in the innovative design part of the competition.

The current report presents the details the system engineering approach used in the design of the Élise aircraft, the electronics and control systems integrated in the vehicle and finally the mission planning regarding the AUVSI 2010 competition and present some safety issues regarding out vehicle and flight plan.

2 Systems Engineering

2.1 Product Development Process

The prototype presented by Team Élise at the 2010 student UAS competition is the result of a complete product development process (PDP) that guided the team through the various phases of the project. A diagram shown at Figure 1 illustrates the PDP that is described in this section. The initial steps of this analysis were based on the requirements of the competition: the actual problematic associated to aerial surveillance was defined and the requirements were derived from the rules of the previous editions of the competition (the 2010 competition rules were not published as the project was in its start-up phase). At this point, the team identified the need for the capability to perform vertical take-offs and landings and decided to include this feature as an additional and innovative requirement in the design process. The functional specifications (functions) were then derived from the requirements, associating quantitative values to the requirements. These functions were used throughout both concept generation and detailed design phases to ensure that the aircraft would comply with the rules of the competition and be able to perform on competition day.

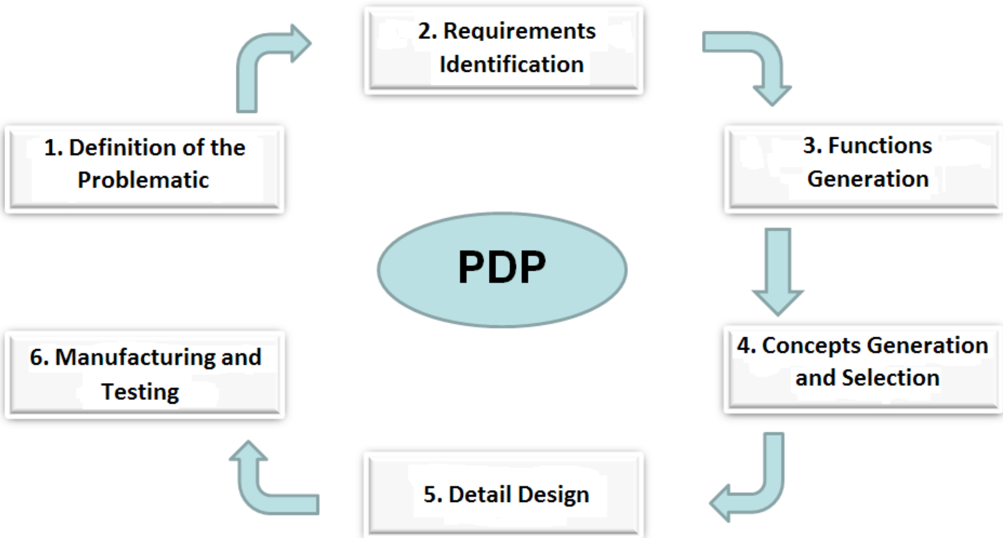

Figure 1 – Product Development Process

The greatest part of the work was performed during concept generation and detailed design phases. Many different concepts for the aircraft's systems and sub-systems were proposed by the team using various concept generation tools, such as brainstorming. The selection of a final concept was done using convergence tools. Iterations by the usage of a Pugh matrix, allowing for comparison of concepts between themselves based on criteria derived from the functional specifications, lead to the selection of the final concept. The final concept combines the usual performances of a fixed-wing aircraft to the vertical take-off and landing capability of a quad-rotor. The engines mounted on the wingtips can rotate and, together with the engines mounted inside the fuselage, allow the aircraft to be operated in a quad-rotor configuration as well as in a traditional fixed-wing configuration. The evolution of the prototype through the product development process is shown at Figure 2, where the E3 prototype is the result of the detailed design phase.

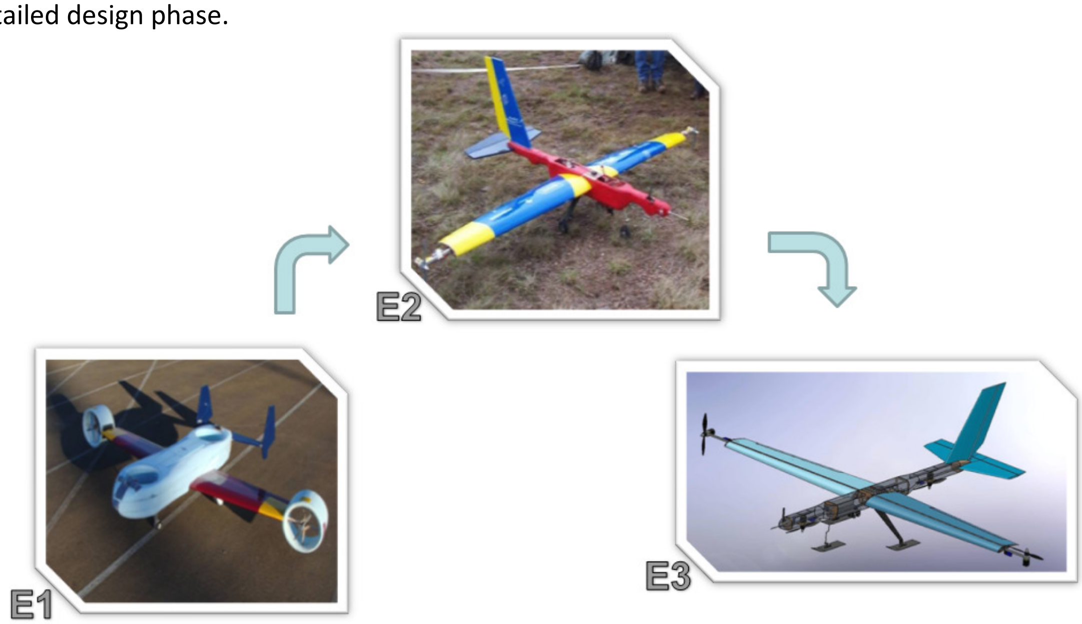

Figure 2 – Prototype Evolution

The E1 prototype was built as a fabrication exercise in the early phases of the project and was quickly abandoned. The E2 prototype was built in parallel with the detailed design phase in order to demonstrate the feasibility of certain concepts, such has the wingtip engines pivot system, and to gain experience in fabrication, especially with composite materials. It was also used to provide a flying platform for the integration and development of the autopilot and to fully develop the horizontal flight capabilities of the aircraft. Every aspect of the design was studied: the aerodynamic performances were optimized for aerial surveillance missions, the structural integrity of the aircraft was validated using a finite element model (in ANSYS) and the detailed drawings and parts lists were produced to guide the manufacturing of the final prototype. The remaining step of the PDP was to manufacture and test the final prototype. Using assembly jigs for precision, the E3 prototype was built according to the detailed drawings and used to validate every functional specification. Tests were first performed in horizontal flight to validate the specifications associated to the aircraft flying in a traditional fixed-wing configuration. In many cases, the flight log recorded by the autopilot was used to extract the desired information on the aircraft's performances. Vertical flight development was initially performed on test benches to adjust the aircraft's pitch, yaw and roll stability while in quad-rotor mode. More testing was required outside in a designated test area to complete the development of the vertical flight prior to the validation of the performances. Finally, the functional specifications related to vertical flight capability were validated through a series of tests and information extracted from the autopilot's flight log was once again useful to this phase of the PDP. In the end, the product development process allowed the team to design and build a unique aircraft, with its own challenging innovation of combining vertical and horizontal flight capabilities.

2.2 AIRFRAME

A large part of the conception effort was directed towards the design of the vehicle's airframe. This included aerodynamic performance evaluation as well as the evaluation and optimization of the airframe's structural strength. Airframe design was also closely related to the material selection portion of the design phase, which is presented in section 2.3.

2.2.1 Aerodynamic Specifications

Through the development process, by knowing precisely what functions we wanted the prototype to accomplish and what was our needs, we could then determine the final aerodynamic specifications required to get the adequate performances in both horizontal and vertical modes. In fact, our needs came directly from the AUVSI competition rules, in which we needed to have about 60 minutes of flight time and a speed that allowed patrolling of the entire search area as well as the observation of targets. The plane has to be relatively stable in order to help the autopilot when gusts and winds are met and to allow for a steady video feed from the camera. Furthermore, in order to achieve vertical flight, we needed a low stall speed so that it could be easy to make the transition between the horizontal and vertical modes. Four engines were also required and they had to be powerful enough to lift and stabilize the entire prototype while in hover. Regarding the payload, the batteries, the engines and the electronic equipment needed to meet these requirements, the weight was estimated. Then, with the weight fixed, an iterative approach was used for aerodynamic design, approach based on the method proposed by Raymer [14]. The control surfaces of the plane were sized, an airfoil profile was chosen for each aerodynamic surface and the performances were derived iteratively from the influence of speed, drag and lift. At the end, the final specifications were validated by control and stability calculations. It is important to mention that the performances were tested and validated in flight with the acquisition of data logs.

Table 1 – Main Aircraft Dimensions and Weights

Final mass	5.2 kg
Wing area	0.5 m^2
Fuselage length	1.5 m
Fuselage width	0.1 m
Span	1.5 m
MAC	0.24 m
Wing root	0.30 m
Wing tip	0.18 m
Airfoil	Selig 1223
Horizontal tail area	0.11 m^2
Vertical tail area	0.08 m^2

Table 2 - General Aircraft Performances

Stall speed	10 m/s
Max speed	25 m/s
Horizontal Autonomy	60 minutes
Vertical Autonomy	10 minutes
Span	1.5 m
Max climb rate	1.2 m/s
Min sink rate	0.8 m/s
Gliding ratio	16.5

2.2.2 Structural Analysis & Load Cases

In order to properly design and evaluate the structure of the Élise prototype, different load cases had to be calculated. These load cases were based on the standard USAR document (UAV Systems Airworthiness Requirements, NATO standard), which is on the way to become a requirement for the design and development of unmanned aerial vehicles for NATO military systems.

Before applying the loads, a good numerical model had to be created to represent the whole of the aircraft and material properties had to be evaluated. Because the plane is mainly composed of composite materials that have unique properties depending on the fabrication process, we decided to test samples on the traction machine in the University of Sherbrooke mechanical laboratory. This step was essential in order to find the material properties of our composite layers.

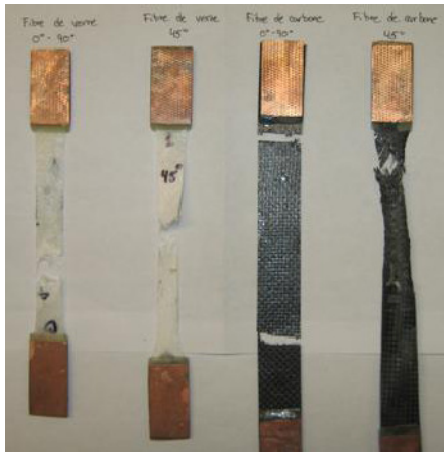

Figure 3 - Tested Composite Samples

Then, a numerical model was developed on ANSYS, a finite element analysis tool that can analyze composite materials. Load cases were applied and the optimization process of the composite layering, quantity and orientation was made. Analytical calculations were compared with the numerical results. This allowed for ascertaining the structural integrity of the aircraft and minimizing the added mass.

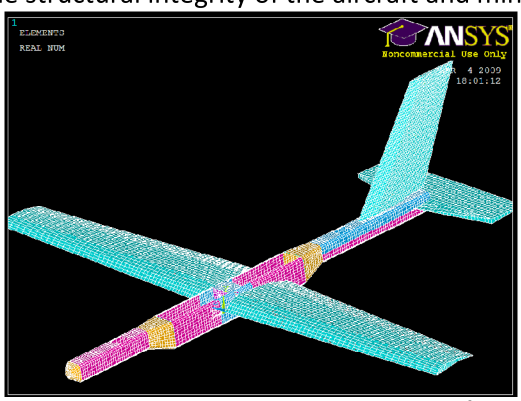

Figure 4 - Numerical Finite Element Model of the Élise Aircraft

2.3 Material Selection

This section will now describe the materials that were chosen for the fabrication of the aircraft. In fact, the decisions were taken in function of three main criteria. Since the most important aspect to consider was mass minimization, the weight of each material was analyzed carefully. In addition, material costs were an issue because we had to find sponsorships to finance the project. Finally, fabrication simplicity was considered.

2.3.1 Composite Materials

Composite materials were selected as the main material to be employed in the structural parts of the aircraft. These materials have a great strength-weight ratio and can easily be used to build curvy shapes such as fuselages and wings. Cost consideration then guided the final choice towards glass fibre because it is cheaper than carbon fibre and aramide fiber. In fact, the team had to anticipate that a great quantity would be required because some iterations would be accomplished and many reparations would be required throughout the project. Accordingly, glass fibre was the perfect solution. The only exception is the wing spar which is made out of carbon fibre because of structural requirements.

Since mechanical properties vary a lot in the literature, depending on which resin, fibre supplier and fabrication method are employed, the team decided to characterize the mechanical properties of its own process. As a result, Young's modulus, shear modulus and ultimate strength (tension, compression and shear) were determined in all directions. With these values in hand, a realistic structural optimization was possible to minimize the mass of the aircraft.

2.3.2 Core Materials

To strengthen the structure, and especially to prevent buckling, composite materials are usually used in a sandwich configuration with other materials. In other words, a lightweight material is positioned between two layers of fibre to make it stiffer. For the fuselage, balsa wood was employed because it is cheap, very light and can be deformed to a specific shape using water. For the wings and stabilizers, light foam was used as a core material. In this last application, it will be explained in the fabrication methods section how the foam is cut to the airfoil shape before fibre application.

2.3.3 Assembly

Using bolts and nuts in a composite material assembly requires particular attention because holes have to be drilled in the structure. In consequence, fibres are cut and it creates a weak region. To solve this problem, reinforcement material is added around the holes to adequately redistribute the stress to the structure. In the aircraft, the most common material used in this situation is aeronautical plywood because it is both cheap and light. Mass minimization even led to the choice of nylon bolts and nuts where it was possible. For instance, the main landing gear and the stabilizers are fixed with nylon bolts. In conclusion, material choices have been significantly optimized all along the project to enhance flight performances.

2.4 FABRICATION METHOD

This section will explain the main fabrication methods used in the construction of the aircraft. The three methods that will be detailed are hot-wire cutting, fibre lay-up and how parts were assembled.

2.4.1 Hot-Wire Cutting

Hot-wire cutting was used to create the airfoil shape of the wing and stabilizers. More precisely, two metallic airfoils corresponding to wing root and wing tip were glued on both extremities a foam block. These metallic shapes were then used as a guide for the hot-wire cutter. Figure 5 shows how the foam looks like after the installation of the spar (on the left) and the metallic airfoils used by this technique (on the right). It is interesting to note that the airfoils were thickened at the trailing edge to prevent the foam from burning in this thin region. To obtain a smooth trailing edge, the extra foam was then hand sanded.

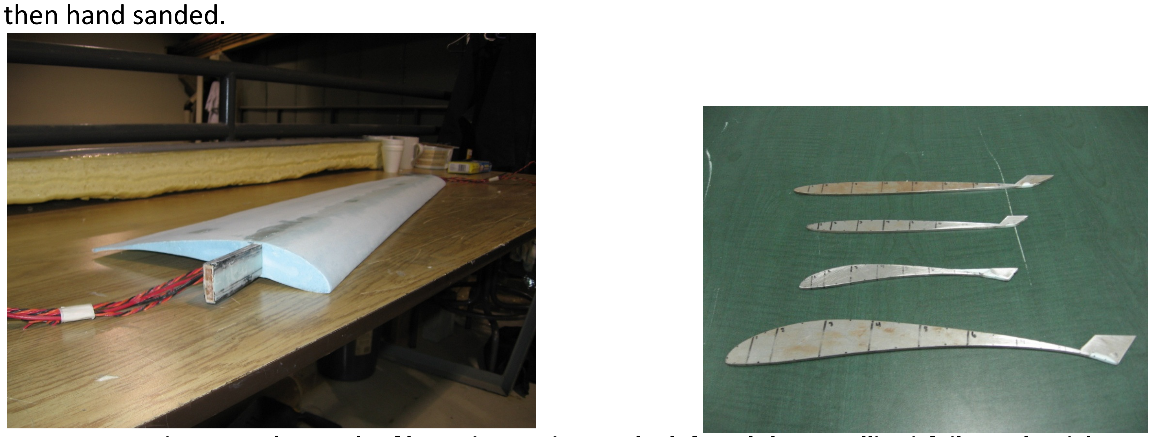

Figure 5 - The result of hot-wire cutting on the left and the metallic airfoils on the right

2.4.2 Fibre Lay-up

Two main techniques were used to apply glass fibres. The simplest was used for wing and stabilizer envelops, which consists in laying fibre on the foam and then spreading resin on top, a technique which is refered to as wet lay-up.

The other method was employed for the fuselage shell. First, a male mould in medium-density fiberboard (MDF) was machined to the dimensions of each half-fuselage. A female replica was then moulded with fibreglass. To obtain the fuselage parts, the fibres filled with resin were positioned in the female replica under a vacuum. These three steps are shown at Figure 6 : the fuselage on the left, the female replica in the center and the male mould on the right.

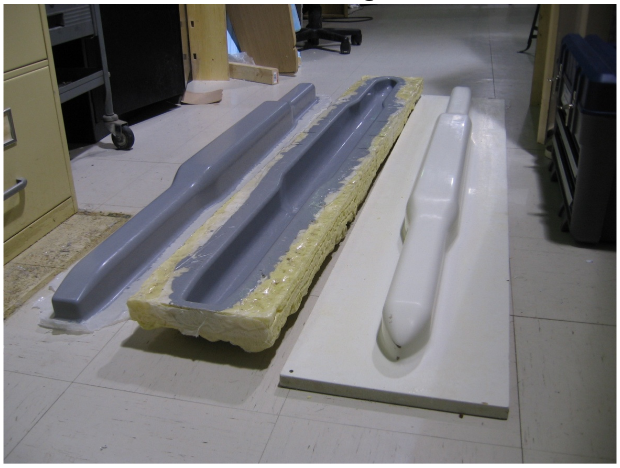

Figure 6 – The three steps in the fabrication of the fuselage

2.4.3 Assembly

A jig was built to assemble critical parts such as the wings, fuselage and stabilizers. This aspect was seriously taken into consideration because both wings have to have the exact same angle of attack in order to generate the same lift. Accordingly, all the holes for assembly points were drilled when parts were supported in this precision jig. Figure 7 illustrates fuselage and wings in the jig.

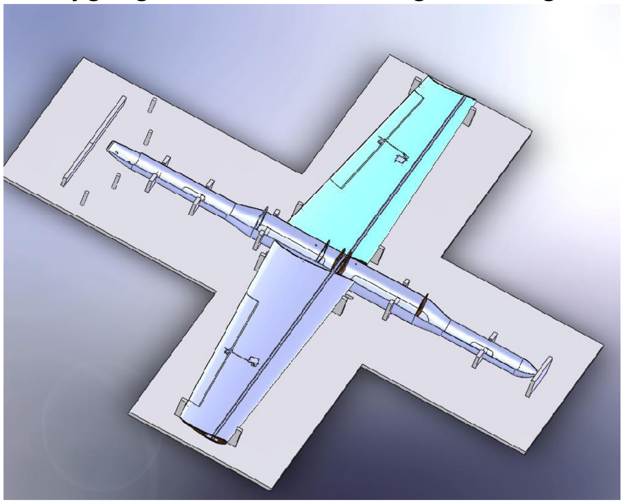

Figure 7 - Fuselage and wings in the assembly jig

2.5 PAYLOAD

The payload is the most important part of the aircraft. It must be carefully chosen in order to deliver critical capabilities to the operators on the ground. This chapter details the payload specifications that will be used to identify the requested targets. The acquisition device will first be described followed by the radio transmission system.

2.5.1 Camera

The choice was not easy as many devices are available out of the shelves. The team compared around 25 different products analyzing their properties, plus and minus points. The chosen camera is a Sony FCB-EX980. It has a 26x optical zoom that allows to magnify on the targets in order to acquire positive ID of the alphanumeric and orientation of the target. Furthermore, with a wide field of view of 54° at the lowest zoom level, this camera allows us to have better situation awareness during transit phases and scanning patterns. It has a high sensitivity which will be useful in low light environments such as a cloudy day. Figure 8 shows a picture of the camera.

Figure 8 - Camera Sony FCB-EX980

To input the operator commands, a FCB-RS Interface Board will be employed. This board will allow us to remotely control the zoom level, contrast, focus, etc. A special 'Pan and Tilt' unit will also be mounted on the aircraft to hold the camera. The SPT100 pan and tilt system will allows a horizontal movement of 180 degrees and 90 degree vertical movement. For mechanical simplifications, we do not intend to look backward. The 180 degree scan movement shall be enough to detect the targets. There is a stabilization algorithm that will help the operator the keep cursor on target while in high level of magnification directly built-in the FCB-EX980.

2.5.2 Video Link

The raw video images are transmitted on a 2.4GHz signal via a 1000mW radio transmitter mounted onboard. A directional antenna is then employed to capture this signal. It will then be amplified and passed to a standard television or monitor via a RCA cable. The mission will be recorded and some playback will be done in case of uncertainties on the targets locations or characteristics.

3 Electronics and Control

3.1 AUTOPILOT SELECTION

The autopilot is the main component of our UAV: it stabilizes, controls and communicates with the different parts of our plane.

An autopilot is a very complex piece of equipment; here follows a brief explanation of its components. Firstly, it's composed of an electronic platform and supported by a software known as the

ground control station. This platform is equipped with captors that provide data on the UAV's attitude. With this information, the autopilot can adequately manipulate the aircraft's control surfaces and propulsion systems to stabilize the aircraft and execute the commands sent by the controller.

In our project, the choice of an autopilot was pretty simple, as we had a requirement that very few autopilots offer. We wanted our autopilot to be able to control our aircraft in two distinct modes: as a standard fixed wing plane and as a quad-rotor configured craft. After some research, we discovered a commercial autopilot from a company called MicroPilot which was made for helicopters. Since we are a mechanical engineering team, hence not specialized in computer programming, a commercial solution with technical support was what we were hoping for. After some talks with the company, we concluded that the $MP2128_{HELI}$ (shown in Figure 9), was the answer to our needs.

Figure 9 - MP2128Heli Platform

3.2 MICROPILOT $MP2128_{HELI}$ OVERVIEW

The $MP2128_{HELI}$ is the latest product from MicroPilot and can handle forward flight of fixed wing planes as well as the vertical takeoff and maneuvering of helicopter-like crafts. The platform weighs 28 g and is preprogrammed with PID feedback loops that control the plane's different servomotors based on the feedback from the integrated sensors.

The $MP2128_{HELI}$ uses three 2g, 3 axis accelerometers, two pressure sensors, a sonar for low altitude and a GPS system. These instruments permit an inertial attitude stabilisation using angular accelerometers with an absolute positional reference. They are used to measure how the vehicle is rotating in space. Generally, there is at least one gyroscope for each of the three axes: pitch, roll and yaw. Using the information from the sensors, the microcontroller continually calculates the current attitude of the plane. First, it integrates the sensed acceleration over time to figure the current velocity on each axis. Then, it integrates the velocity to calculate attitude. Finally, it stabilizes the aircraft based on the information collected by the sensors. The advantage of this kind of system is that gyroscopes are nearly unaffected by environmental conditions. One thing that we need to be aware of with this kind of control is the refresh rate of the sensors. A refresh rate around 50 Hz is normally sufficient to react quickly enough in case of wind gust, so we do not need to worry since the refresh rate of the $MP2128_{HELI}$ is 200 Hz.

But for us, the most important feature is that it has a built-in model to handle quad rotors. Another interesting feature is that you can purchase a developer kit to customize it to a certain extent. Using this kit, we can override the default settings programmed in the autopilot and write our own. This is the tool that will make transition between vertical and horizontal flight in midair possible.

3.2.1 Horizon Overview

The $MP2128_{HELI}$ autopilot is provided with software called $HORIZON^{mp}$ that is used as a ground control station. As such, it can track the aircraft moving on a virtual map and monitor the aircraft status. Finally, $HORIZON^{mp}$ allows its user to transmit waypoints to the aircraft while it is in flight and modify the plane's trajectory as desired. Also, it can record the plane's reaction information and location and record

sensor data like a video camera. The following picture is an example of a generic window of the HORIZON^{mp} software.

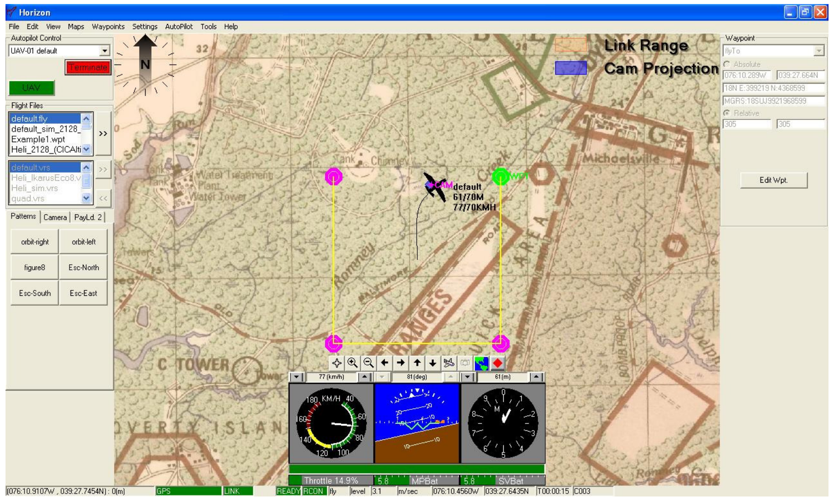

Figure 10 - HORIZON Generic Window

Figure 15 shows a series of indicator scales that provides the aircraft's flight information. The instruments panel includes an airspeed indicator, an artificial horizon and an altimeter. Above these main instruments are the airspeed indicator, the heading and altitude display. Finally, three gauges monitor the throttle, the main battery and the servos battery.

Finally, HORIZON^{mp} is also an autopilot simulator that can simulate flight path, wind conditions, radio and engine failure and even catapult launches.

3.3 Communications System

It is mandatory to have a reliable communication system so that we can retake control of the aircraft if a dangerous situation occurs. This system is what puts everything together in a flying machine. It can be divided in three portions based on the functions accomplished: manual control, autonomous flight and camera system. In order to understand the different relations between these systems and the plane, Figure 11 presents a schematic of the communications system. The three branches of the system will be detailed in the following sections.

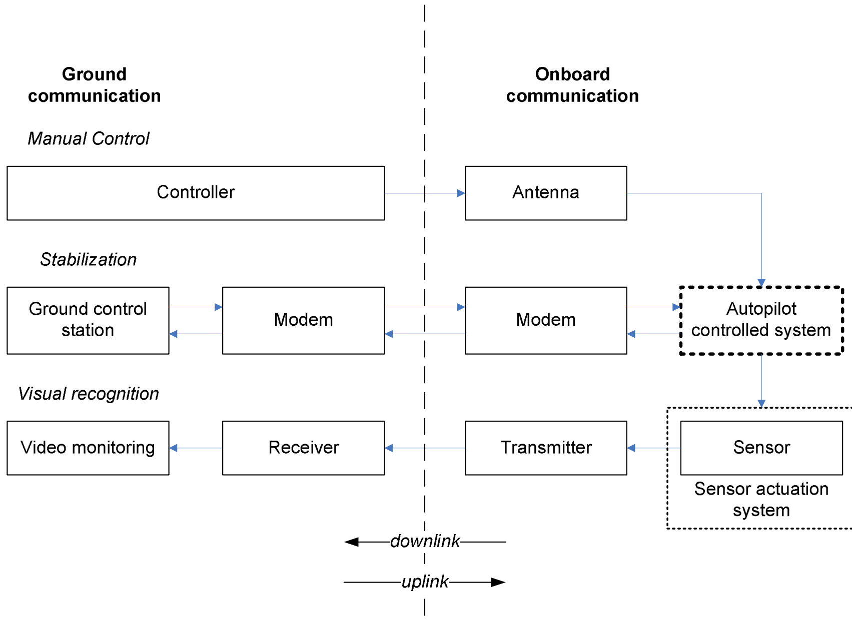

Figure 11 – Communications System Schematics

3.3.1 Manual Control

Basically, radio control of a model vehicle is divided into two categories: surface models and the UAV. Both categories are not operated at same frequencies to avoid interference between users. Therefore, by regulation, model aircrafts use reserved channels in the 72 MHz bandwidth zone. We have chosen to stay in the radio frequency (RF) bandwidth zone because they are multidirectional, which eliminates the need for the ground station's signal emitters and/or receptors to be aligned with the aircraft.

To choose the type of controller, we have to consider the number of functions that have to be accomplished and the communication range required. For our application, we require a communication range of three kilometers, so there is no problem in using the RF bandwidth to relay manual control.

3.3.2 Autonomous Flight

When flying autonomously, navigation commands can be pre-programmed in the autopilot or transmitted through the GCS. In this second case, the uplink is used to transmit commands from the ground control station to the in-flight aircraft. Those commands are given on a computer via the software provided with the autopilot, in our case the HORIZON^{mp} software. On the other hand, the downlink uploads data concerning the UAV's attitude to the GCS. Both data links are made via RF, but on a frequency different from manual control. We are doing this using an Xbee Pro XSC Wavecard functioning in a five kilometers range on 900 MHz frequency. In order to receive and transmit these informations, we chose to use a 8dbi patch antenna which has the advantage to be omnidirectional, so we don't have to point the plane with it while flying.

3.3.3 Camera System

First of all, because of our lack of knowledge in automatic visual recognition, we decided to dedicate someone at the task of analyzing the camera output in real time while our aircraft is flying over an interest area. In order to do that, we need to relay the video signal back to the GCS.

As for the transmitter, the link with the camera has to be made in the ISM bandwidth. In order to choose the appropriate frequency, we have to verify the frequency used by the available devices on the

market. Afterward, we narrowed our choices between 900 MHz, 2.4 GHz and 5.8 GHz. Since the 915 MHz is already taken by a more important system, the Wavecard, we will take 2.4 GHz for the video transmission as it is the frequency that allows for the longest communication range possible. In order to extend the range since we had to take a higher frequency, we will use a high gain (12 dBi) directive antenna. Table 3 presents the frequency chart that we will be using during the AUVSI competition.

Table 3 - Frequency chart

Receiver and remote controller	72 MHz
Xbee Wavecard	900 MHz
Video and audio transmitter	2.4 GHz

4 Mission Planning

A good mission begins by a good planning. In this section we will present the specifics task and the ground crew roles.

First of all, our main ground crew will be composed of a Safety pilot, a Ground Control Station operator (GCS) and a payload operator. Each will have predefined tasks to be completed by and at the time the airplane is airborne.

4.1 SAFETY PILOT ROLE

The Safety Pilot is responsible for the main airplane inspection, to be sure the batteries are full and the moving parts operational. He will complete a safety checklist prior to flight. He will have visual at all time on the aircraft during the mission and is a qualified radio-controlled aircraft pilot.

4.2 GCS OPERATOR

The GCS operator role is responsible for setting up the GCS and the preflight communications with the airplane. He is the one that creates and load the flights plans. He is responsible of re-tasking the UAV during the mission if required. The GCS operator will complete a GCS checklist prior to flight.

4.3 PAYLOAD OPERATOR

The payload operator role consists in establishing all the pre-flight video check and transmitter/receiver setup. The operator will perform the payload operation during all the flight phases. He will be the one who notes the targets location and the physical attributes of the targets.

4.4 PRE-FLIGHT PROCEDURES

The pre-flight procedures begin when with the briefing. It is the responsibility of the safety pilot to gather his crew around and make a pre-flight briefing. During this speech he will explain the different parts of the mission in order to be sure every member of the crew is aware of the mission. The briefing will include: Take-off, climb, mission entry route, search area and boundaries, target locations, exit route, landing approaches, engine out on takeoff option, lost communication route and hold point, etc.

Following the briefing, The GSC operator will pre-program the flight plan as specified by the safety pilot. The payload operator will make sure all the video communications are established and functional. The safety pilot will proceed to the aircraft inspection.

4.4.1 Mission Accomplishment

A typical mission accomplishment would be an autonomous takeoff from the strip followed by a climb of three hundred feet (300ft) in calm air (winds less than 15 knots) and a straight climb off five hundred feet (500ft) in turbulent air (winds above 15 knots). Then the aircraft will head for its hold point situated at a safe location and altitude (500ft). Following the judge's signal, we will head to the search area following the entry route previously established.

4.4.2 En-route Section

The en-route mission plan will be divided in multiple segments allowing us to fly at the requested altitude. In this section the payload operator will manually proceed to a sweeping scan technique. At an angle of 30˚ down from a forward viewpoint, the operator will pan from +90˚ to -90˚ and so on. As he spots something, he will manually lock on target and give the requested specifications; position, shape, orientation, alpha num, color, etc.

4.4.3 Search Area Section

The search area mission segment will be performed in a "come and go" grid pattern. The pattern will be constructed in order to avoid any "No fly zones" or "restricted operation zone (ROZ)". The same payload operation process will be employed until target detection which means a sweeping scan. Upon accurate target detection, the operator will communicate the GCS operator to orbit above the target until satisfying identification. Then we will go on with the mission.

4.4.4 Return to Base

The return to base command sent to the aircraft, it would head for the predefined exit point at the required altitude. If the altitude is not good or there are conflicts within the airspace, the aircraft will be put into a hold pattern near the exit point until commanded to proceed. The aircraft will then follow the exit route to the landing hold point.

4.4.5 Landing Procedure

The aircraft will begin its decent in a circle pattern at the hold point. When reaching the FAF altitude, the GCS operator will then choose when to send the aircraft to its final approach. We will attempt an autonomous landing. It will be to the safety pilot to oversee the process and to regain control would the aircraft not be able to auto-land.

4.4.6 Lost Communication Route

Should the aircraft loose communication with the Ground control station, and out of range of the safety pilot, there is a pre-programmed route triggered by a lost communication counter. This counter is usually set to 120 seconds. The lost communication route would begin at the exit point of the search area and follow the exit route to a hold point at an altitude of three hundred feet (300 ft) AGL. This hold point will be close enough to allow the safety pilot to gain control of the aircraft.

5 Safety / Failsafe systems

Safety was a major concern in the aircraft's design and the choice of the autopilot. The following section details the major systems and autopilot failsafe implemented on the airplane. It includes the crew coordination and preflight briefing, the autopilot failure routines and the systems safety features.

5.1 Crew coordination and preflight briefing

Each ground crew member`s tasks are very well defined and described in the Mission Planning section of this report. The safety pilot plays the role of team leader and is responsible for crew coordination and communication.

Before each flight session, the crew members follow a pre-flight routine to ensure our aircraft is in flying condition. The prescribed steps of this routine are presented below:

1. Verify the RC controller's parameters and power voltage;
2. Visual check:
   a. There are no slivers on the propellers;
   b. The control surfaces are correctly connected;
   c. The electronic cables are well fixed on the board and servos;
3. Adjust gravity center position;
4. Check battery voltage and powered on the aircraft;
5. Test the control surfaces and the engines;
6. Verify the GPS and modem communication with the GCS;
7. Check the quality of the video signal;

✓ Aircraft ready for take-off.

5.2 Autopilot failsafe

The MP2128Heli autopilot includes a pre-programmed Failsafe Module with pre-defined behaviours in case of a signal loss. If signal loss occurs for 30 seconds, the autopilot executes a Return Home command. After a signal loss of three minutes, the autopilot commands the Failsafe Module to switch over to manual safety pilot control. In addition to autopilot commanded control changes, the safety pilot can override the autopilot at any time the aircraft is within range of the R/C transmitter. In the event of a signal loss where the airplane is unrecoverable by the pilot, the GCS operator can trigger a Kill Switch to terminate the mission.

Furthermore, MicroPilot allows its user to define patterns that automatically run in the event that the autopilot detects an in-flight failure. These in-flight failures are either recoverable in the air or unrecoverable and must be fixed on the ground. If an in-flight failure is recoverable, the error pattern will automatically end once the error is cleared and the interrupted command will be restarted. If the error is unrecoverable, then the pattern will continue to run continuously and result in a forced landing of the plane. The following sections present some of the possible error failure scenarios.

5.2.1 Control Failure

This failure state is activated if the pitch, roll or airspeed limits that we have set are exceeded. In the event of a control failure, there is not much that can be done other than activate the manual RC control. In the event that the RC link fails, the aircraft will fly back "home" to its takeoff location.

5.2.2 Loss of GPS Signal

If the GPS signal is lost, it is suggested to roll the plane level to maximize the probability that the signal will be re-acquired. In the case that the signal has not re-acquire a lock, the plane will descend to ground level at a controlled speed. The engine will not be stopped as the UAV may reacquire GPS signal as it is descending.

5.2.3 Ground Control Station Failure

In the case of a HORIZON^{mp} communication link failure, the autopilot will allow some time to re-establish the link. If the reconnecting procedure fails, the plane will fly back "home" to its takeoff location.

5.3 Safety Systems

Aside from the autopilot, the aircraft design presents safety features in case of recovery from an emergency landing. These features include an onboard power switch that allows the recovery team to turn of the power supply of all three batteries at the same time. Furthermore, the aircraft wings and its control surfaces will be painted with bright colors to ease ground recovery.

6 Conclusion

The Élise team has thus produced an innovative UAV design that it thinks will meet and exceed the objectives of the competition. A strong emphasis on the system design approach and methodology has yielded a fully functional VTOL capable autonomous UAV combined with long range flight capabilities. A truly simultaneous engineering approach had to be followed, involving all of the sub-teams to achieve a working prototype; the main problem to be solved, as mentioned before, was mass minimization which was a requisite for hovering flight as available thrust was limited.

The use of a top-of-the-line autopilot platform allows for complete in-flight autonomy and GPS coordinate tracking. The use of a quality camera system helps to locate and identify targets of interest on the ground and will surely allow the team to be competitive in the AUVSI 2010 competition.

A proof of flight video showing the Élise air vehicle in flight near the University of Sherbrooke's campus can be found online[1]. The image below shows the aircraft itself as photographed in December 2009.

[1] Proof of flight video - **http://www.youtube.com/watch?v=AEsNVx7D8Mo**

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